Resistance mechanisms of birch to bronze birch borer

Vanessa L. Muilenburg[1], Pierluigi (Enrico) Bonello[2], Daniel A. Herms[1]

[1]Department of Entomology, The Ohio State University, Ohio Agricultural Research and Developmental Center (OARDC), Wooster, OH
[2]Department of Plant Pathology, The Ohio State University, Columbus, OH

contact: muilenburg.1@osu.edu

Abstract

- Outbreaks of bronze birch borer, *Agrilus anxius*, a North American wood-boring beetle, have occurred periodically over the last 100 years, causing extensive tree mortality.
- Little is known about mechanisms underlying tree resistance to wood-boring insects, but previous studies have suggested that secondary metabolites and wound periderm (callus) tissue may play a role.
- North American birches (*Betula* spp.) are much more resistant to bronze birch borer than exotic species that lack a coevolutionary history.
- We compared patterns of constitutive phenolic chemistry and the rate of wound periderm formation in phloem tissues of North American paper birch (*B. papyrifera*) to exotic European white birch (*B. pendula*).
- Six phenolic compounds were in higher concentrations in phloem of paper birch than in European white birch and might be involved in resistance.
- There were no interspecific differences in rate of wound periderm formation.

Introduction

Bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae), is a North American, flatheaded wood-borer that infests birch (Fig. 1). Larval feeding produces galleries that girdle the phloem, which disrupts nutrient transport and eventually kills the tree (Fig. 2). Periodic outbreaks of bronze birch borer have occurred over the last 100 years. The most recent outbreak occurred in the Great Lakes region killing over 100 million birch (*Betula* spp.) trees (Jones et al. 1993).

Fig. 1. Bronze birch borer adult and D-shaped exit hole.

Birch exhibit substantial interspecific variation in resistance to bronze birch borer. North American trees (e.g. paper birch, *B. papyrifera*) are much more resistant than exotic trees (e.g. European white birch, *B. pendula*) (Herms 2002). Little is known about mechanisms of resistance of angiosperm trees to wood-borers. However, authors have speculated that resistance may be based on integrated physical and chemical phloem defenses. Constitutive and induced secondary metabolites (e.g. phenolics) may inhibit larval growth (and thus velocity of phloem excavation) to the point that they may be encapsulated by wound periderm (callus) tissue induced by feeding injury (Fig. 3).

Fig. 2. Bronze birch borer larva and gallery.

Fig. 3. Wound periderm growth in response to larval feeding.

Objective: to compare constitutive phloem phenolic chemistry and rate of wound periderm formation of resistant paper birch to susceptible European white birch.

Methods

Common Garden Study Site

Phloem was sampled from 14-year-old paper birch and European white birch growing in a common garden in Wooster, OH (Fig. 3).

Fig. 3. Common garden birch plantation.

Phenolic Analysis

Phloem extracts were analyzed for phenolic compounds using high pressure liquid chromatography with a photodiode array detector (HPLC-PDA) at 280 and 320 nm.

Wound Periderm Formation

Rate of wound periderm formation in response to experimental wounds were measured monthly (Fig. 5).

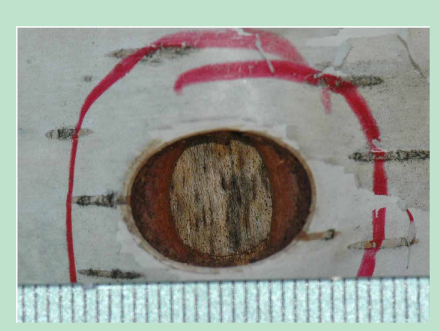

Fig. 5. Wound periderm formation in response to experimental wounds.

Statistical Analysis

Principal component (PC) analysis explored the phenolic variation between species (MINITAB v15). Area of HPLC peaks and wound periderm growth rate were analyzed using ANOVA (SAS 9.1).

Results

- 14 compounds were analyzed in detail (Fig. 6) revealing quantitative and (potentially) qualitative differences between the two species.
- PC 1 and 2 showed clear variation in phloem chemistry between species (Fig 7A).
- Phenolic compounds 1, 10, 11, 12 contributed most variation to PC 1, while phenolic compounds 3, 4, 5, 9 contributed most to PC 2 (Fig 7B).
- Six compounds were significantly higher in paper birch than in European white birch (1, 7, 10, 11, 12, 14) (Table 1).
- There was no difference in wound periderm growth rate between species (Table 1).

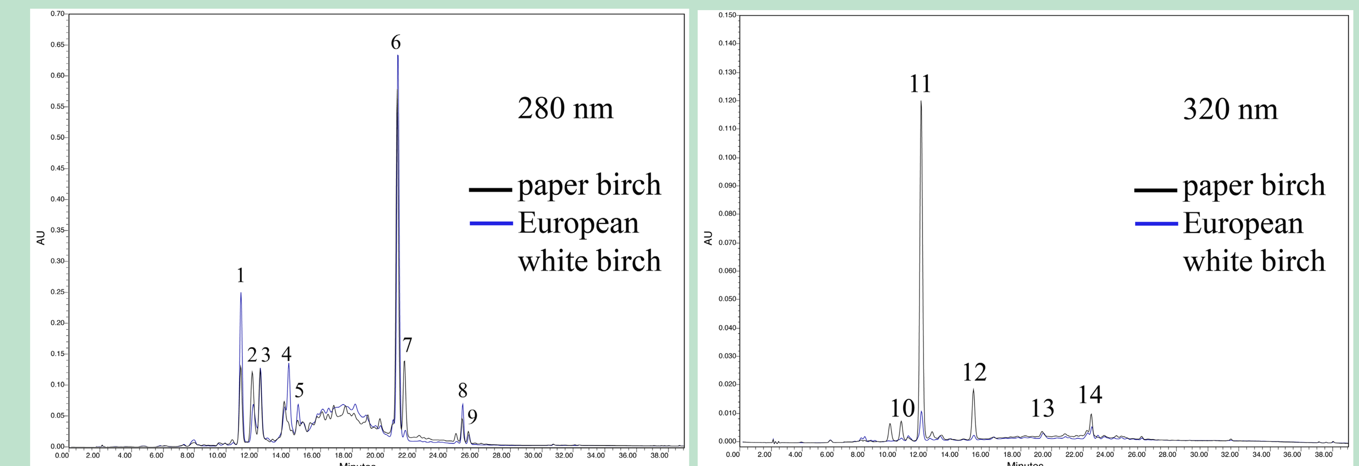

Fig. 6. Phenolic profiles of paper birch and European white birch phloem.

Table 1. Relative phenolic concentrations (peak areas) and rate of wound periderm formation between species using ANOVA.

	paper birch	European birch	*P* value
Physical defenses			
wound periderm (mm/day)	0.054	0.053	0.963
Phenolic defenses (peak area)			
peak 1	1.11×10^5	6.27×10^4	<0.0001
peak 7	9.52×10^5	1.69×10^5	<0.0001
peak 9	7.47×10^4	6.46×10^4	0.243
peak 10	6.16×10^4	2.27×10^4	<0.0001
peak 11	1.34×10^5	2.47×10^5	<0.0001
peak 12	1.95×10^5	4.59×10^4	<0.0001
peak 14	9.67×10^4	4.62×10^4	<0.0001

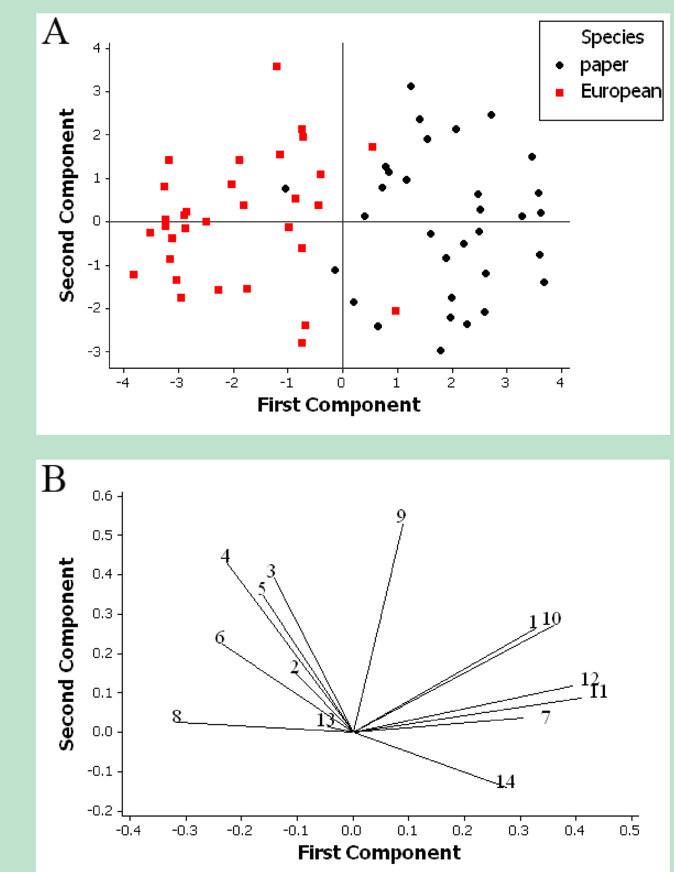

Fig. 7. Clear separation of species based on phenolic chemistry. a) Ordination plot. b) Loading plot.

Conclusions & Future Work

- Six constitutive phenolics (peaks 1, 7, 10, 11, 12, 14) occurred in much higher concentrations in paper birch than in European white birch and may contribute to increased resistance of paper birch to bronze birch borer.
- Work is underway to identify phenolics.
- Phenolics from phloem extracts will be integrated into artificial diets to confirm any toxic or deterrent effects.
- The two birch species had identical rates of wound periderm formation. However, rapid wound periderm formation could still be an important component of resistance if it interacts synergistically with targeted chemical defenses selected via coevolution.
- This work focused on constitutive phenolic chemistry, but induced defenses may also contribute to resistance and will be studied in 2008.
- We are conducting research at the ASPEN FACE site in Rhinelander, WI to determine effects of atmospheric CO_2 and ozone levels on bronze birch borer colonization and expression of these physical and chemical defenses in paper birch.

References

Jones, E.A., D.D. Reed, G.D. Mroz, H.O. Liechty, and P.J. Cattelino. 1993. Climate stress as a precursor to forest decline: paper birch in northern Michigan. 1985-1990. *Canadian Journal of Forest Research*. 23:229-233.

Herms, D.A. 2002. Strategies for deployment of insect resistant ornamental plants. In: *Mechanisms and Deployment of Resistance in Trees to Insects*, M.R. Wagner, K.M. Clancy, F. Lieutier, and T.D. Paine, eds. pp. 217-235. Kluwer Academic Publishing, Dordrecht, The Netherlands. 332 pp.

Acknowledgements

We thank Christopher Wallis for assistance with the HPLC-PDA and everyone in the Herms' lab for help with this project.